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RESEARCH REVIEWS

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COVER PHOTO: The man with the spray gun is helping to fight the war against insects which the Armed Forces is continuously waging. The brush, where insects might lurk in the daytime, is sprayed with a combustible and then set afire. Another common method of control—the use of insecticides—is losing its effectiveness as insects are building up a resistance almost as fast as new insecticides are developed. To find out the reasons for this and what scientists are doing about it, see pp. 18-22.

Research Reviews endeavors to report briefly highlights of technical progress in research by Navy laboratories and contractors and the development of important naval research facilities. Articles which meet these broad criteria and possess a good degree of readability are welcomed. Manuscripts and changes of address should be sent to Code 250, Office of Naval Research, Washington, D. C.

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The Naval Research Reserve

This man is one of many whose jobs should be considerably easier when some of the theories about simplified inventory control can be put into practice in the military establishment. Much has been said about standardization of equipment, and it is not "just talk." Scientists at Princeton University are working hard on the problem.

Military Inventory Control

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. . . is a research associate at Princeton, where he received his doctorate. His book, "The Theory of Inventory Management", will be published by the Princeton University Press in March.

Among the most complex problems currently faced by economists and supply personnel is that of controlling the inventory levels of the National Military Establishment. The situations encountered differ considerably from those in private business.

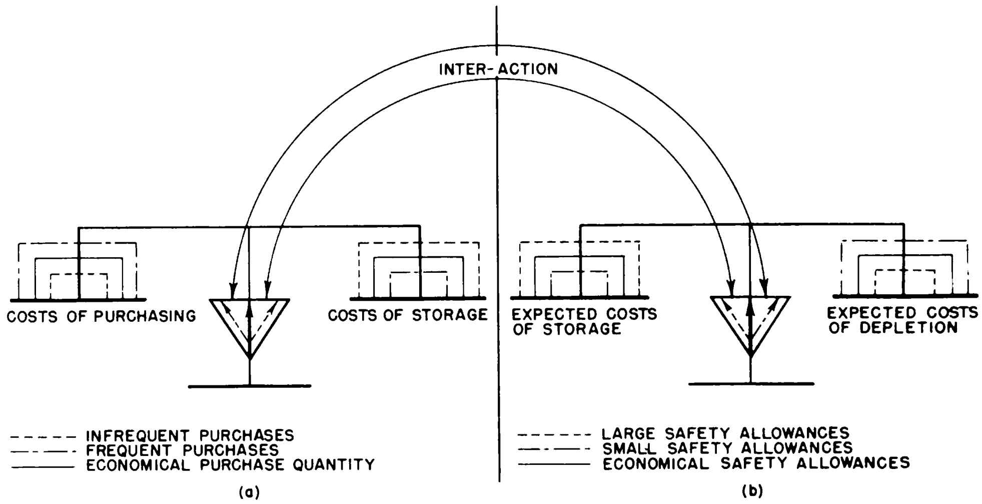
The first and most obvious difference is the fact that the number of items involved in military inventories is vastly greater than the number encountered in even the largest corporations. For example, R. H. Macy's is said to carry about 500, 000 items, the General Motors Corporation about 120, 000, and the J. C. Penny Company only 25, 000, whereas the Navy alone carries several million different items. In fact, most Supply-Demand Control Points have many more items under their cognizance than even the largest corporations. Unfortunately it does not necessarily follow that inventory control methods applicable to large firms can be expanded to cope with the larger military problem, for it is likely that the nature as well as the magnitude of the problems change as the quantity increases.

Aside from the number of items, the size and complexity of the military organization are much greater than in private business. Moreover, there are no objective standards by which one can evaluate the performance of the component parts of the organization. Currently many people are engaged in studying Organization Theory in an effort to solve some of the problems that arise in connection with performance evaluation.

A second major difference stems from the greater degree of uncertainty in the demand for military equipment. Of course demand for various items in the "military economy" changes drastically from peacetime to wartime, and also with changes in public opinion and politics. In time of partial mobilization like the present, uncertainty about when and if a war will start, how long it will last, and how it will be fought, all make the situation extremely complicated. To estimate accurately the level of demand, one must know the answer to these and many other questions.

The private entrepreneur, on the other hand, may be faced with a demand that varies greatly between prosperity and depression, but the magnitude of these changes is not nearly so large as the changes in military demand. Furthermore, the transition from depression to prosperity is likely to be much more gradual than the transition from peace to war.

A third and perhaps the most striking difference between the military and private enterprise is the lack of a profit mechanism in the military establishment. In business, the costs of adding units to inventory (i.e., carrying charges, such as interest, obsolescence, depreciation, insurance, storage, etc.) can be realistically compared with the expected costs that result from not adding these units (the loss of profits and good will, special ordering costs, etc.). If it costs less to add units of an item to inventory than it costs not to add them, they should obviously be stocked. In the military establishment, however, there is at present no adequate way of measuring the costs of "running out of stock". What value can one assign to running out of ammunition, to the loss of a few hours of flying time, or to the lack of adequate clothing? Values must be assigned, but in the state of present knowledge this can only be done arbitrarily. Actually when decisions on military inventory problems are made, this sort of arbitrary value is implicitly assigned.



Calculating economical purchase quantities and safety allowance levels.

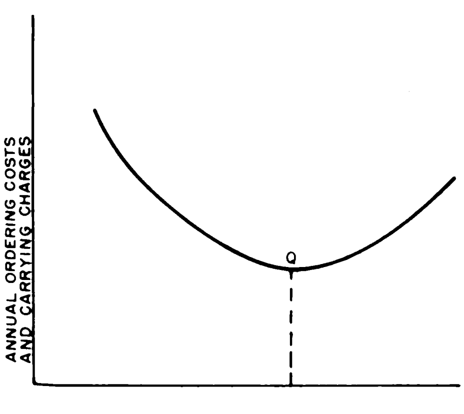
Another difference between civilian and military inventory control problems lies in the fact that it is essential that the impact of the military program on the economy be estimated, for it is likely to be large. For example, over one-half of last April's inventory increase in the economy was accounted for by a rise in military stockpiles. In this connection, there is much need for further study of the economic effects of prolonged periods of partial mobilization. Private entrepreneurs may often be able to neglect general equilibrium considerations, but military planners cannot possibly do so.

In spite of the many difficulties that confront the military planner, a study of the methods used in private industry reveals ways in which the present military inventory control systems may be improved. One method that has already been applied in several large corporations involves the calculation of economical purchase quantities and safety allowance (reserve stock) levels. The figure above indicates some of the basic principles of this system. The calculation of purchase quantities involves balancing the costs of acquisition, which decrease as the purchase quantity is increased, against the costs of storage that increase as the purchase quantity is increased. The figure opposite (left) shows how ordering costs and carrying charges are related to the purchase quantity. The lowest point on the curve indicates the most economical purchase quantity, which varies systematically with changes in sales. A typical variation of this kind is shown in the figure at the right. It should be noted that the economical purchase quantity varies much less than proportionately with sales. The calculation of economical purchase quantities may be viewed as roughly equivalent to a calculation of the appropriate length of the period between orders. Such a calculation reveals that rather than reviewing and ordering all items quarterly, one should review some more frequently and others less frequently. At the present time, exceptions to the policy of quarterly reviewing are made only in the case of items of small value and low carrying charges (such as nuts and bolts) where it is intuitively clear that the costs of ordering frequently are not justified. A systematic consideration of this problem for all items may be needed.

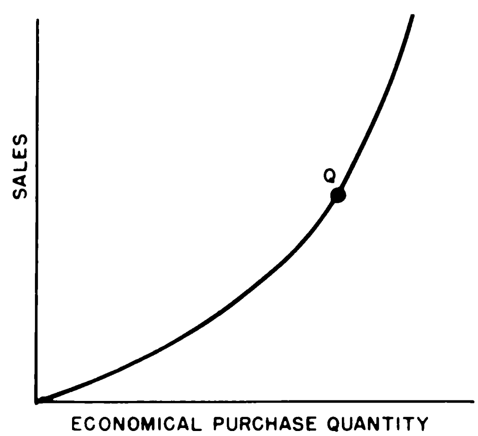
The determination of economical safety allowance levels involves a balancing of the expected costs of "running out" against the costs of storage. Like the economical purchase quantity, safety allowances for maintaining the same protection against chance variations in demand may be shown by well-known statistical laws to vary proportionately with the square root of demand. The system is not quite as simple as it seems, however, because the two calculations are not independent of one another, as the arrows at the top of the figure on p. 2 indicate.

The savings effected by the use of such an inventory control system in business have been substantial. Table I indicates the extent to which safety allowances in the Bell Telephone Laboratories (1) vary with changes in the probability of depletion. It clearly demonstrates the fact that reserve stocks can be significantly lowered if the entrepreneur is willing to run out of the item occasionally. It would seem sensible to have large reserve stocks of important items and smaller reserves of items of lesser importance.

Similarly, large savings can sometimes be brought about through the calculation of economical purchase quantities. Table II is based on J. C. Robbins' study (2) of the drug department of a large department store. It shows that the department could halve its combined purchasing and storage costs for epsom salts by placing orders at less frequent



This graph shows the relation of ordering costs and carrying charges to the purchase quantity.



A typical variation of economical purchase quantity is shown on this graph according to changes in sales.

Table I

Average Number of Years Each Item Will Go Out of Stock Once	Inventory Required (in $)
1	76,000
2	100,000
5	134,000
10	167,000
Never	276,000

intervals. The example also illustrates a fact that surprises most businessmen—namely, that turnover rates can be too high as well as too low. For sixteen items the department incurred ordering costs and carrying charges of $88 instead of $38. The high turnover rate was obtained at the expense of excessive ordering costs.

Naturally, the question arises as to whether this inventory control system has anything to offer the military establishment. The determination of economical purchase quantities indicates that gains are possible through centralization, since the number of purchases is reduced. For operations of the size of the military, however, those gains may not be available. In the first place, the large order size is likely to necessitate purchases from more than one plant, thus making additional orders necessary. Secondly, the effect of the size of purchase on the price must be considered. Large military orders are frequently accompanied by higher prices.

Though methods are not known that are adequate for estimating the costs of running out of military items, industrial experience leads one to be optimistic concerning this latter problem. For corporations have effected large improvements in inventory control by using extremely crude estimates of the costs of running out. In some cases, items are divided into as few as three different categories according to importance, and different safety allowances are set for each category. Allowances are set so that the firm may expect to run out of very important items once every ten years, out of moderately important items once every five years, and out of unimportant items every year or two. If such simple schemes have been successful, there is every hope that military items may be divided into rough classes of this sort and safety allowances set accordingly.

It is all but certain that in military matters estimates of requirements are not always equally reliable. Differing amounts of experience with different items, uncertainty about the nature and size of military programs, and difficulty in calculating usage rates for various items contribute to this uncertainty. A more efficient inventory control system would result if such variations in reliability were taken into consideration. It should be possible to reduce the safety allowance for items whose demand can be accurately predicted and to increase allowances for items for which the demand is most uncertain.

It is less obvious but equally true that setting safety allowances at a certain number of months' supply is also inappropriate for any single item when demand for that item varies. Safety allowances set in this manner result in a constant ratio of safety allowances to demand. For example, if the quarterly demand was 300 units, a safety allowance of one month's supply would be 100 units. If quarterly demand increased to 1200 units, a safety allowance of one month's supply is equal to 400 units. As indicated above, a safety allowance of 200 units provides the same degree of protection for a quarterly demand of 1200 units as a safety allowance of 100 units provides for quarterly demand of 300 units. Thus, the degree of protection against depletion has been varied, although it would seem desirable to maintain it constant.

Other inter-item differences that should be considered in determining safety allowances are differences in lead time (the time between reviewing items and their actual delivery), and differences in carrying charges. The former may affect safety allowances in quite a complicated fashion. (3) All these differences affect the balancing operation represented in the figure on p. 2.

A further source of improvement in military inventory control lies in standardization, of which we have heard so much lately. The wastage involved in duplication of items is apparent. For example, if an item is broken into two separate classes when there is in fact no distinction, a safety allowance is necessary for each class. To maintain a constant degree of protection against depletion, the safety allowances for the two subclasses must be considerably higher than that for the combined class, although the total demand would (by definition) remain the same. Hence, aside from the wastes involved in additional stock taking, ordering, etc., larger inventories are actually required. Thus, even if the economical purchase quantity was determined by a balancing of ordering costs and carrying charges, the purchase quantities would differ greatly according

Table II

Epsom Salts - Annual Sales $319

Purchase Quantity	$100	$75	$50	$25	$10	$5	Actual $18.54	Optimum $66.33
No. times per year orders are placed	3.19	4.25	6.38	12.76	31.9	63.8	17.2	4.81
Annual costs of placing orders at $60 per order	1.91	2.55	3.83	7.66	19.14	38.28	10.32	2.89
Average Inventory	50.00	37.50	25.00	12.50	5.00	2.50	9.27	33.17
Carrying Charges at 8.7 per cent	4.35	3.26	2.17	1.09	.43	.22	.81	2.89
Combined ordering costs and carrying charges	6.26	5.81	6.00	8.75	19.57	.39	11.13	5.78

to the classification system used. Suppose a certain type of screwdriver had been listed separately as items A, B, C, and D, instead of together as item T. If the demand for A, B, C, and D is equal, purchase quantities will be such that their sum will be approximately twice what they will be for class T, thus doubling both carrying charges and ordering costs.

The application of "simplified practice," i.e., the elimination of varieties of products, has been studied by the National Bureau of Standards. Their study has shown possibilities of great reduction in the variety of items, which might lead to saving through lower costs of carrying inventories. For example, the number of wheelbarrows was reduced from 125 to 27; the number of ducts, pipes, and fittings for warm air heating and air conditioning was reduced from 5,580 to 759; and the number of varieties of cans for fruits and vegetables has been reduced from 200 to 39.

There is much room for the introduction of simplified practice into the National Military Establishment. Recent attempts by the Munitions Board Cataloging Agency are a step in this direction. The Munitions Board's Cataloging Program is intended to eliminate item duplications and serve as an aid to standardization as well as to facilitate transactions between the various services by providing a common language. Although it is still too early to appraise the final results of the Munitions Board Program as a long-run goal, it certainly constitutes an improvement. The difficulties in converting are considerable (it is estimated that it will take several years to implement the program), and the Navy has emphasized that it may prove logistically disastrous if the need for war mobilization arises during the process of conversion.

Some of our analysis has been considerably simplified, perhaps oversimplified. If an inventory control system is to be useful, all the important variables must be included in the analysis in a realistic fashion. It is likely that an extremely complicated set of inter-relationships between some of the variables exists, inter-relationships that are very difficult to put in to mathematical form. Nevertheless, there is hope that fairly realistic "loss functions" can be evolved to express the loss to be expected from carrying inventories, from depletion, from ordering costs, etc. The objective would be to minimize this loss.

It should be emphasized that functions of this sort are in no sense a substitute for human judgment. Implicitly or explicitly, in determining inventory levels, some decisions must be made about the expected demand, the level of carrying charges, and the relative importance of inventory items. The objective is to make the best use of estimates of the behavior of the variables, rather than to supplant the estimation process.

Electronic computers are likely to play an ever-increasing role in military inventory control in connection with loss functions. (4) These computers make it possible to compute the expected losses resulting from a tremendous number of alternative inventory control decisions and to facilitate the selection of optimal policies. Much research on inventory problems will undoubtedly have as its objective the integration of the best available information concerning the nature of the loss functions and modern computers that are adequate for handling these functions. Although a great deal of work remains to be done, the prospects for substantial improvements in inventory control procedures in the foreseeable future are good.

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(2) Robbins, J. C., A Scientific Method of Stock Control for Staples, Journal of Retailing, February, 1941.

(3) Tompkins, C. B., Lead Time and Optional Allowances...an Extreme Example, George Washington University, Minutes of a Working Conference on Mathematical Problems in Logistics, Appendix I to Quarterly Progress Report No. 1, December 1949 - February 1950.

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ASTIA-Clearing House for Technical Information

In the years since World War II, new efforts by government and industry have brought scientific research into the planning for national defense on a scale far outstripping any previous peacetime activities. As a result, technical information growing out of the many and diverse organizations engaged in defense-connected scientific work began to pile up at a rate that demanded some major changes and improvements in the established service for handling and distributing this kind of information.

As an approach to the problem, a study was undertaken by the Special Committee on Technical Information of the Research and Development Board. This led to the establishment of the Armed Services Technical Information Agency (ASTIA) in May 1951. Two organizations already in existence were merged into the new agency: the Navy Research Section at the Library of Congress and the Central Air Documents Office (CADO) at Wright-Patterson Air Force Base, Dayton, Ohio.

ASTIA as now organized undertakes to collect, index, catalog and provide storage for scientific and technical reports of the military departments and their contractors. The service of abstracting the information is another valuable contribution of ASTIA, and the results of this exacting condensation are published periodically (about twice a week for unclassified material) and circulated as a "Technical Information Pilot." The existence of this big information center is an outstanding example of the direction in which organizational improvement is likely to go in the critical years ahead.

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Predicting Teaching Ability

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Teaching is a complex phenomenon. Many attempts have been made to analyze teaching ability with a view to predicting it. In general, however, the results have been discouraging. More recent investigations suggest that teaching skill may be a complex of abilities rather than a single trait or behavior pattern. If this is true, then a more fruitful approach to analyzing and predicting it would be to study its various aspects independently before attempting to study the ability as a whole.

One aspect of a teacher's competence is his skill in establishing the good relations between himself and his class which are essential to efficient learning. When an harmonious atmosphere prevails there are few incidents requiring disciplinary action, a situation which promotes unity, interest, and cooperation among the students.

When harmonious relationships between the teacher and students do not exist, quite a different situation develops. For example, the teacher may attempt to dominate the class. He may be successful in doing so and rule with an iron hand, creating an atmosphere of tension, fear and submission. If unsuccessful in his attempt to dominate, on the other hand, he may become nervous and distraught in a classroom characterized by frustration, inattention, lack of respect, and numerous disciplinary problems. In either case, both teacher and students dislike school-work. There is a feeling of mutual distrust and hostility and teacher and students attempt to hide their inadequacies from each other. The teacher tends to think in terms of his status, the correctness of the position he takes in classroom matters, and the subject matter to be covered, rather than in terms of what the students need, know, and can do.

The attitudes of the teacher probably are the key to the problem of predicting the type of teacher-student relations he will be able to maintain. Investigations carried on by Dr. W. W. Cook and his students at the University of Minnesota during the past ten years indicate that the attitudes of teachers towards students and school work can be measured with high reliability and that these attitudes are significantly correlated with the teacher-student relations found in the classroom. The Minnesota Teacher Attitude Inventory has emerged from these researches. It is designed to measure those attitudes of a teacher which predict how well he will get along with students and indirectly how well satisfied he will be with teaching.

These attitudes seem to be fairly stable by the time the person is halfway through college and they are not materially affected by either the teacher education program or early teaching experience. Students in a teacher education curriculum improved slightly in these attitudes as a result of theory courses; they showed no change during practice teaching; and they deteriorated slightly during their first year of full-time teaching. Apparently these attitudes are so firm by the time the person has reached this stage of his education (or possibly this age) that the usual teacher education program has only a minor and temporary effect.

The attitudes measured by the inventory seem to be related to the choice of a teaching field. Those who choose to go into early childhood education score significantly higher on the inventory as a group than do those planning to teach academic or special subjects. On the other hand, people who choose to go into specialized teaching fields (industrial arts, physical education, art or music, etc.) score significantly lower than either the academic or early childhood education groups. These differences have been observed both before students begin their education for teaching and after they have had experience. They further confirm the idea that these attitudes are rather stable by late adolescence. If this is true, then a measure of these attitudes can be used to predict who will be a good teacher in terms of teacher-student relationships, and consequently they can be used in the selection of teachers.

To date, three studies have been conducted which show that teachers' scores on the attitude inventory can predict the relations between teacher and students as well as almost any other psychological phenomenon can be predicted by tests (for example predicting school grades from an intelligence test). These studies were conducted in widely separated places—Pennsylvania, South Carolina and Missouri—with substantially the same results. The nature of the teacher-student relationship was determined from ratings by the school principal, from ratings by members of our research team who observed the class in session, and from an inventory by the students about "My Teacher".

Modern test construction usually follows one of two methods in developing an instrument for prediction. One is strictly empirical; item analysis is used to select items or questions which will predict most efficiently. The result is usually an instrument which is difficult if not impossible to interpret psychologically because of its omnibus characteristic. The other method is to develop factorially pure (and psychologically interpretable) tests, the scores of which may then be appropriately weighed to predict the criterion. The Minnesota Teacher Attitude Inventory was constructed by the empirical method. We know what the inventory will do (that is, what it will predict), but very little about what it is.

With ONR support, the attitude inventory is being analyzed to determine what psychological factors it contains in order to know more precisely what is being measured, and possibly to improve the measurement of each one of the possible factors. If the inventory contains several independent factors, then the identification of these factors is desirable—perhaps essential—in order to extend the use of the inventory beyond the public schools. Our ultimate goal is to modify the Minnesota Teacher Attitude Inventory so that its effectiveness in predicting teacher-student relationships in a variety of adult education situations can be determined.

Who's Who in Naval Research

Dr. Elliott Montroll

Elliott Montroll is a rare phenomenon in this day of specialization—a versatile scientist. Though he remains faithful to his first love—basic research in the field of physics—he has strayed far enough to acquire a reputation as a research administrator of some ability. Moreover, he has the gift, which many abstract thinkers lack, of being able to apply his theoretical knowledge to the solution of practical problems. For these reasons, and many others, Dr. Montroll was given a cordial welcome when he returned a few months ago to head ONR's Physical Sciences Division.

Like most theoretical physicists, Dr. Montroll hit his stride early. At the age of 36 he has quite a list of accomplishments behind him. He got off to a fast start by acquiring his Ph.D. in mathematics from the University of Pittsburgh at the age of 23 (his B.S. was in chemistry). Thereafter he had a succession of teaching and research positions at various Universities: Yale (where, as a Sterling research fellow, he worked with Lars Onsager), Cornell, Princeton, the University of Pittsburgh and the University of Maryland. "About all I've done is teach, conduct research, and write papers" is the way Dr. Montroll puts it, "None of it is very interesting or dramatic in a popular sense."

Others probably would not take such a lukewarm view of Dr. Montroll's accomplishments. For example, they might find his contribution to the development of the atomic bomb both interesting and, in its eventual application, dramatic. Dr. Montroll's special field is statistical mechanics—which means that he applies the laws of probability to the solution of problems in physics which involve large numbers of atoms or molecules. His reputation in this field led to his appointment, in 1942, as head of a group of scientists who had the job of working out theoretical problems associated with the design of one of the large-scale isotope separators now at Oak Ridge. The one which Dr. Montroll helped to develop was very successful and is, in fact, still in operation.

Probably Dr. Montroll would consider this just a "sideline" to his more theoretical work recorded in some 25 published papers. At ONR his colleagues consider the Navy fortunate to get such first-rate talent on its roster of research administrators. No doubt part of the enthusiasm for Dr. Montroll is due also to his personal qualities. He has the easy-going temperament and quick humor that make personal relationships as easy for him as elementary physics. This knack for getting along with people probably comes in handy at home, where his five children (two boys, three girls) keep things lively. They account for most of his spare time which, as Dr. Montroll says, is spent "either in the zoo or the Smithsonian Institution."

A Down-To-Earth View of Space Flight

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In many respects, the rocket capitol of the United States is White Sands Proving Ground, N. M. Here, in the 40-mile-wide basin between the San Andres and Sacramento mountains, rocket vehicles designed and built in widely different parts of the country are tested and fired. This is where the Viking established a record altitude for single-stage miles, the highest altitude reached by a man-made vehicle. Among the rocket technicians who meet and discuss their work there is a saying: "You have either just had trouble, or you are now having trouble, or you are about to have trouble." A few successful flights have received wide publicity but the public seldom learns about the many rockets which do not fulfill predictions. Nor is it explained that great odds were overcome to produce a record flight - a flight that would have been prevented by the failure of one component in several thousand. In a rocket everything must work. This realization leads to a down-to-earth attitude toward space travel.

Why is it so difficult to go much higher than we have been? It is because the engineers have caught up with the scientists and have almost exhausted our store of basic knowledge. The time lag between the discovery of a new material, technique, or principle and its utilization has become increasingly short. The public has come to expect a constant flow of products, each more wonderful than its predecessor. But the engineer who has always drawn his ingredients from the cupboard of basic research now finds that the cupboard is bare. He must wait for new ingredients.

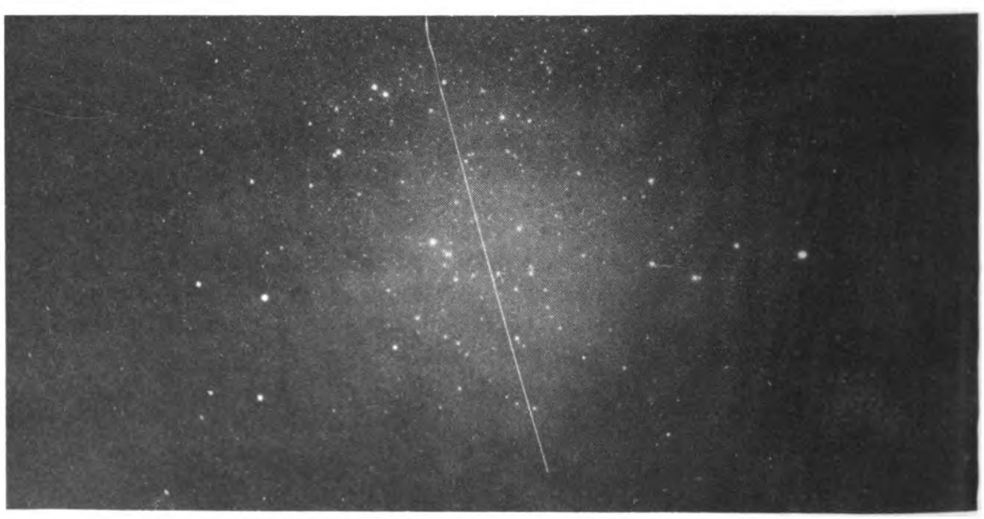
This is why plans for space travel and designs for space ships are based on a meagre store of scientific knowledge and a large amount of speculation. Of course there is a place for speculation if it is clearly labelled "speculation", and if its purpose is to stimulate interest in the subject. But a great deal of harm would probably be done to this country's defense effort, and to the cause of space flight itself, if the United States were to undertake any of the fantastic projects for a space ship that have been proposed in the last few years.

We can illustrate the difference between the speculative and the scientific approaches to space travel by imagining two scientists, whom we shall call "Scientist A" and "Scientist B". Scientist A is holding up a ladder which extends far into the sky. A typical American whom we shall call "Taxpayer" approaches and engages him in conversation.

Taxpayer: "What are you doing with that ladder?"
Scientist A: "Do you see that light high in the sky? That light is called space travel and I intend to climb this ladder to reach it."
Taxpayer: "I notice that many of the rungs are missing."
Scientist A: "Don't worry about that - I will supply the missing rungs as I climb."
Taxpayer: "But how will you balance yourself?"
Scientist A: "I will climb so fast that I will reach the top before the ladder topples. Then I will hang from the light and I won't need the ladder any more."
Taxpayer: "Well, let's see you climb it."
Scientist A: "I forgot to tell you - I need ten billion dollars before I can start."

And before Scientist A can finish that sentence, the taxpayer has disappeared. Now we see Scientist B, who is building an immense pyramid, block by block. Construction is not far advanced and the highest block is only a few yards above the ground. The taxpayer approaches.

Taxpayer: "What are you doing?"
Scientist B: "Do you see that light —— ?"
Taxpayer: "Your friend, Scientist A, told me about it. Are you trying to reach it? Is that why you're building the pyramid?"
Scientist B: "Yes —— and it's very hard work. Sometimes I have to search all day to find one block and when I need one of a particular size and shape, it may take weeks or months to find it."
Taxpayer: "Are you going to ask me for ten billion dollars?"
Scientist B: "Heavens no! I wouldn't know what to do



Trajectory of the Viking 6, fired at midnight, December 12, 1950, as observed at White Sands by the Schmidt telescope of Harvard College.

V-2 (left) and Viking (right) taking off at White Sands.

with that much money. But I could use a few million dollars for modern equipment. You see, as the pyramid grows higher, it becomes increasingly difficult to lift the blocks."

Taxpayer: "I can't see any return for that investment. Your progress is too slow. I will be gone and forgotten before you get close to space travel. But don't be discouraged. If you ever get to the place where you need only a dozen more blocks, I will buy that dozen!"

Where do we stand today with respect to space travel? To answer this question let us consider the feasibility of building a manned, earth-returnable rocket on the basis of what we have done, rather than what we think we can do. A manned earth-returnable rocket is a vehicle which travels some distance away from the surface of the earth, which carries one or more human beings as passengers, and which includes provisions for ensuring the safe return of these passengers to the earth's surface. It is not considered essential that the vehicle itself return in a useable form.

Altitude is the primary factor in any consideration of the feasibility of a manned, earth-returnable rocket. Two altitudes, 15 miles and 50 miles, are significant because they define the boundaries of three regions that can be considered separately. These are the regions between the ground and 15 miles, where feasibility has actually been demonstrated, the region between 15 and 50 miles, where feasibility can be shown, and the region above 50 miles, where a decision on feasibility is not possible today.

According to recent unofficial but reliable reports, a Douglas Skyrocket has reached an altitude of 15 miles and its pilot has returned safely to the earth's surface. For an altitude of 15 miles, then, feasibility has actually been demonstrated.

Feasibility can be shown for a manned, earth-returnable rocket that reaches an altitude of between 15 and 50 miles, even though no human has ever reached these heights. Rockets have been built which can ascend 50 miles and which can carry the necessary payload involved in transporting a human being. The significance of the 50-mile height is that parachute recovery has been successful only below this altitude. Entire Wac Corporal rockets and instrument sections from Aerobees have recovered by parachute from altitudes up to 50 miles. Moreover, the accelerations encountered on the powered ascent are within the tolerance limit of human beings and the maximum velocity is sufficiently low so that, for a vertical ascent, the vehicle skin temperature will not tax the capacity of known materials and techniques of construction. The most important feature of a flight to less than 50 miles is that its duration will be brief – a matter of several minutes. For this reason, many of the difficult problems that would be involved in higher flights (effects of cosmic and solar radiation, meteor collisions, free fall in a vacuum, etc.) will be ignored. Moreover, because the flight will be so short, it will not be necessary to make elaborate provision for the necessities of life: Food, oxygen, elimination of wastes and maintenance of ambient temperature.

The most important problem in this region will be one of reliability of the rocket, for on this depends the man's chance for survival. The concept of reliability must enter into the design of every component, subassembly and operating system of the vehicle. The factors of safety here are entirely different from those presently used in the design of sounding rockets. The probability of returning a man safely 99 times out of 100 is a very much smaller number than the probability of a safe return 1 time in 100.

Above 50 miles the situation is entirely different. Attempts at parachute recovery of instruments have not been successful. Depending upon the altitude to be reached, the accelerations could be beyond human tolerance limits and vehicle skin temperatures above the melting points of available materials. The Viking rocket, which reached an altitude of 136 miles, could have carried a man, but no one could have ensured his safe return. In fact no one could even have calculated the probability of his survival; there are too many "unknowns" at this stage of the game. For example, if the duration of the flight is long, the effects of cosmic and solar radiations must be considered—a difficult problem, since the nature and quantity of these radiations in outer space have not been fully determined and we are only beginning to study their effects on living cells. Another risk hard to assess is the probability of meteor collisions; although this hazard has been estimated and various schemes proposed for eliminating it, none have ever been tested.

Besides these "unknown" difficulties there are some which are very easy to predict, though they are not so easy to solve. For example, in a long flight elaborate equipment requiring a continuous power source will be necessary to provide the human passenger with the necessities of life. Such equipment, as well as that needed for guiding the vehicle, will have to be automatic in operation because the long flight would probably impose terrific physical and physiological strains on the passenger. Thus, many machines will have to perform a great diversity of functions with precision. A tremendous amount of investigation, measurement, and test will have to be conducted before one can assess the magnitude or importance of

Examining some of the data-bearing debris which has been collected.

most of the problems involved. At present, we cannot even estimate the feasibility of building a successful manned rocket because of insufficient information.

If we cannot build a space ship today, what can we do to advance the cause of space travel? The answer is that we can discover the ingredients for future engineering and thus replenish the cupboard of basic research. Before we can attempt to transport human beings in a ship that orbits around the earth, we must produce a practical, reliable, unmanned satellite. To do this we need better, more efficient rocket power plants, and unfortunately our progress in recent years has been slow. Anyone who can operate a few machine tools can build a rocket motor and make it work; it is one of the simplest engines for converting chemical energy into mechanical energy. But no one fully understands the theory of combustion in a rocket motor—one reason why every rocket manufacturer in the country is having difficulty in improving his product. We need more research on fuels, on high-temperature metals and ceramics, and on novel methods for cooling the inner walls of rocket motors and the outer skins of high speed airframes. Finally, we need more and better sounding rockets—rockets which can ascend far above the pedestrian altitudes thus far achieved. Sounding rockets are our best laboratories for space flight research. They are, indeed, the predecessors of future space ships, but they are the remote, not immediate ancestors.

Atomic energy has been envisioned as an almost limitless power source for the propulsion of a rocket. The application is important, but its value has been overestimated, for some limitations of present-day rockets still apply. For example, there is a practical limit on the temperature at which a rocket motor can operate and it matters little whether the heat has been generated by nuclear or molecular reactions. All rockets are propelled by the ejection of matter and our atomic rocket, like our present rockets, will have to carry a working fluid. The major gain to be achieved from the use of a nuclear power plant lies in the fact that this fluid can have lower molecular weight than the exhaust gases of a chemical combustion. But there are also disadvantages involved in the use of nuclear-powered rockets—for example the danger to instruments and personnel from damaging radiation. Despite such difficulties, the potential use of nuclear power for the propulsion of rockets cannot be ignored. Before we construct the first atomic-powered rocket vehicle, however, we must investigate the use of nuclear rocket power in the laboratory and in the test pit.

Hand-in-hand with rocket power gains must come progress in the field of electronics. The navigation of a space ship, communication between the ship and earth, and automatic control of the complex equipment necessary for human survival in outer space—all pose tremendous problems for the electronics scientist.

I will not attempt to list or classify the many other investigations that evolve from our desire to send a human being into outer space—for example, research that falls into the category of human engineering. Many such problems and a few of the answers have been ably presented by Dr. Haber[1]. This type of research can proceed, in fact, must proceed—concurrently with vehicle development if we contemplate human travel in outer space. Herein lie many years of research for the biologist, physiologist and psychologist. In this connection, when asked what fields of scientific endeavor are embraced by the subject of space travel, a co-worker of mine replied, "It would be easier to name the fields that are not required." When pressed further he was unable to name any field of science that could be eliminated categorically.

Thus far, research contributing to space travel has been accomplished as a by-product of other projects—largely military. A better rocket motor is a better rocket motor—whether it is intended as a guided missile or as a sounding rocket. Conversely, many investigations which further space travel have been supported because they also contribute to our national defense. The time has come, I believe, for someone or some group to assess clearly the problems involved in space flight and to determine what we are doing and what we could do to make further progress. Such a group should consist of able and respected representatives of government, science, and industry and might be sponsored by the National Science Foundation recently created by Congress.

I would commend to such a group the following procedure:

(1) They should make a thorough study of existing knowledge on space flight and then prepare a list of the problems which must be solved before it can be achieved. Such a list will be lengthy and far from complete.

(2) They should select from the list those problems which can be tackled with the techniques and tools available today.

(3) They should examine every project in the country which is closely allied to space flight. Many of these projects are classified

[1] In a paper entitled "Manned Flight at the Borders of Space" presented at the Centenial of Engineering, Chicago, Sept 1952

for security reasons and could only be revealed to a select group.

(4) They should recommend to government and industry present and future support for those projects which are making a worth-while contribution to space flight.

(5) They should recommend the timely initiation of investigations which could yield important results in the near future.

A large share of our scientific talent is now enlisted in the effort to resist and deter foreign aggression. When some of this talent can be released from the task which is so urgent today, and when the country can afford the manpower and money required, the recommendations of the proposed space flight committee would constitute a practicable program to support work.

Searching for instruments in the crater made by a V-2 rocket impact.

Now comes the question—why do it at all? This country should not and, I feel confident, cannot be frightened into attempting space flight before it is technically feasible. The alleged military value of a space ship is as speculative as today's space ship designs. Moreover, we can only speculate about the material benefits that might be derived from the exploration of outer space.

I am reminded of Aesop's Fable about the farmer and his sons. A farmer, being on the point of death and wishing to show his sons a way to success, called them to him and said, "My children, I am now departing from this life; but all I have to leave you, you will find in the vineyard."

The sons, supposing that he referred to some hidden treasure, went to work as soon as the old man died with their spades and plows and turned up the soil over and over again. They found no treasure; but this thorough tillage yielded a firmer vintage than they had ever reaped before and more than repayed the young husbandmen for all their trouble.

Similarly with space travel: The knowledge we will have to gain, the techniques we will have to master, the machines we will have to build, will bring more material benefit to the earth's population than any gold or uranium we may find on Mars or Venus. The value of space flight is in the doing of it.

Why Are Insects Harder to Kill ?

Charles D. Michener

. . . chairman of the Department of Entomology at the University of Kansas, received his Ph. D. in that field from the University of California. He has done extensive research on the classification of bees and other insects.

During the last world war and for a short time afterwards, many entomologists, and the public as well, felt that we were on the road to nearly perfect control of certain important pests by means of the new insecticide, DDT. This material was merely the first and most famous of a long series of fine synthetic insect poisons and more are being developed each year. Not only have they made possible more efficient insect control, but they have indirectly made medical history by controlling insect carriers of disease. Yet today, before our very eyes, one after another of these insecticides is becoming ineffective in the control of some of our most important pests. Chemists and entomologists have become involved in a contest with these insects—a race between the development and use of new insecticides on one side and the ability of the insects to develop insecticide resistance on the other. It is a race which man may lose eventually unless he changes his methods and uses some other attack. The number of new insecticides cannot be infinite. It would be a real hardship and in some places a serious health hazard to go back now to the control methods of the Thirties.

It is well known that any organism must be well adapted to its environment in order to survive. It is further known that one of the principles of existence is that when environment changes, organisms must either die, move, or adapt themselves. When we spray with an insecticide, we change the environment by adding a chemical and we hope for the first alternative, death of the insects. As second choice, we hope that at least they will move away. Instead, we sometimes get the third alternative--that is, the insects evolve, thus becoming adapted to the changed environment. In other words, they become resistant to the insecticide.

Our studies at the University of Kansas are designed to shed light on the evolutionary problems involved. Most evolution goes on at such a slow rate that it is difficult to study and, moreover, it cannot easily be brought into the laboratory. The development of resistance is a sort of evolution, fundamentally not different from natural evolution, but well adapted to precise laboratory investigation. We hope to obtain certain basic data about evolutionary mechanisms and at the same time contribute to the practical problem of how to avoid or reduce the development of resistance.

Knowledge of resistance of insects to insecticides is far older than is usually realized. Several kinds of insects developed such resistance long before 1944. As early as 1914 San Jose scale, a pest which had previously been easily killed by lime sulfur, began to kill trees in spite of repeated treatments with this insecticide. Oil insecticides came into use in the control of this pest because of the inefficacy of lime sulfur.

The next important insect pest which developed resistance was the codling moth or appleworm. Growers noted for years that, in order merely to maintain a certain standard of "wormlessness" in their crop, they had to increase the number of sprays as well as the concentration of lead arsenate in these sprays. When the matter was finally investigated, it was found that strains had developed which entered the apples promptly after hatching from the eggs and thus ate less poison than the nonresistant strains which nibbled here and there before entering. The resistant strain exhibited no true physiological resistance, but had instead a behavioral characteristic that was a selective advantage in the presence of poisons on the apples.

Within a few years of the first really extensive use of DDT, insects were developing resistance to it. Thus, in 1947, house-fly resistance was reported in Italy, where DDT had been widely used by American troops in 1943. In 1948 considerable resistance had also developed in parts of the United States where DDT had been recommended for several years as a spray for barns and other fly breeding places. By 1950 a survey revealed not a single house-fly population in this country that was not at least somewhat more resistant to DDT than the so-called "normal" or susceptible strains. Other insecticides, of course, have replaced DDT in the control of houseflies. Unfortunately, and to the great alarm of all concerned, DDT-resistant flies also develop serious resistance to other insecticides in one-half to one-third the number of generations that is required for similar evolution by nonresistant forms. Therefore strains have developed or are now arising which are resistant to virtually every one of the recently developed synthetic insecticides (such as chlordane, lindane, and dieldrin) and many fly populations are resistant to two or more insecticides. In the laboratory, strains have been developed which are so resistant that 2000 times as much DDT, on the average, is required to kill a fly as was required for ordinary nonresistant flies when DDT first came into use.

In addition to houseflies, mosquitoes of several kinds and perhaps a dozen other kinds of insects have developed a resistance to DDT in recent years. Space does not permit a historical summary of all of these. It must suffice to point out that resistance has doubtless arisen in many more insects than is now known. One of the latest reports, not yet confirmed by laboratory tests, is that bedbugs are getting hard to kill with DDT.

What causes resistance? Actually too little is known of how resistant insects differ from the others. As already stated, the so-called resistance in the codling moth is due to a change in behavior, not to real physiological change in the insect. On the other hand, some resistant strains of houseflies are larger and have thicker cuticle than the susceptible ones. Presumably part of the resistance of the tougher specimens is due to the fact that DDT and similar insecticides are less readily absorbed through their thick cuticle. Increasing knowledge indicates, however, that much or all of the resistance in most houseflies is due to physiological factors, not to merely mechanical ones. Much work remains to be done on this but it is reported that DDT in the bodies of resistant flies is rapidly altered to a nontoxic substance known as DDE, while in the bodies of nonresistant flies this does not take place; the DDT remains poisonous and kills the fly.

There is no doubt that resistance is often due to several different factors. In the housefly, strains resistant to one insecticide are usually somewhat less resistant to a second, but can quickly be made more resistant by selection.[1] Evidently some factor, possibly reduced permeability of the cuticle, makes these strains somewhat resistant to any insecticide that enters by way of the cuticle. Further resistance, specific for the particular insecticide, is probably of a different nature.

How did such resistance evolve? First of all it is apparent that the factors responsible (genes, etc.) were disadvantageous in fly populations before the advent of DDT. Had they been advantageous, they would already have become prominent in most fly populations; thus the flies would have been naturally resistant, and DDT would never have been considered a good fly poison. From this information a logical conclusion is that if DDT is removed from the environment, selection will favor the original strain and flies will become less resistant. From the practical standpoint, however, this information may not be too useful for we cannot tell whether reversion will occur in a year or two or will require a century. This is because we have as yet no idea how unfavorable the resistance-conferring genes may be in the absence of DDT.

Our studies deal with the mechanism of evolution of resistance. We have been using the pomace fly, *Drosophila melanogaster*, because of the ease with which it can be reared, the large number of generations it produces per year, and especially because more is known about its genetics than about that of any other organism. We believe that much of the information obtained on its resistance will be applicable to the housefly, but to be sure we are now starting a series of experiments on the latter.

Our work on *Drosophila* consists of experiments in which resistant strains are developed both by rather moderate selection (50 percent survival in each generation after DDT exposure), and by rigorous selection (5 percent survival after exposure, if possible). We are also developing unusually susceptible strains by using for breeding, in each generation, brothers and sisters of the most readily killed flies. At each generation breeding is controlled—that is, the sexes are separated before they have a chance to mate. Later they are mated according to an established plan. DDT is used in the larval food medium and selection thus occurs in this stage, not in the adult stage.

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[1] The selection referred to in this article is of two types. Natural selection is the selective action of external conditions in which characteristics favorable to the survival of the animal or plant are preserved. In artificial selection animals are mated according to a definite plan which will produce given characteristics in the offspring. The type of selection meant is not always specified in the article, but can be inferred from the context.

As explained above, these experiments are designed to get basic data on the way in which selection operates and particularly on ways in which different characteristics of an organism become associated with one another. This matter of association is vital, for we probably never obtain really high resistance except when a number of genes favorable for resistance are associated in a single organism.

We have evolved a working hypothesis on the probable way in which resistance develops which our studies will check insofar as is feasible. This hypothesis proposes that when a population of flies is exposed to DDT, no selection occurs if all individuals are killed; hence there is no evolution of resistance. This is not the case, however, with DDT; like many of the other synthetic insecticides it leaves a residue on surfaces which kills for some time after its application and gradually disintegrates or wears off. Thus if the surface is of a permanent nature[2] (a barn, a house, or a woody plant) a time will come after spraying when not all the flies contacting it will be killed; some will be slightly more resistant than the others and will survive the lessened dosage. If most of the surviving flies of a population are thus selected, a slightly resistant strain is already being developed.

As already explained, the genes conferring resistance are slightly disadvantageous in natural populations. Like many other genes for disadvantageous characteristics, however, they remain in the population. They are usually recessives[3], but they do emerge in rare individuals. Yet they constitute a pool of hidden variability upon which the flies can draw when the environment changes to make these genes advantageous. There is no reason to believe that new mutations[4] are necessary before resistance can arise; selection operates, in all probability, on genes that have been in the population for a long time.

In a large fly population the slightly resistant individuals first favored by selection will no doubt be resistant for several different reasons. Some may have thicker or less permeable cuticle; others will have the ability to detoxify DDT; and the remainder may not usually rest on the sort of surfaces commonly sprayed. No one fly will have all these resistant characteristics because the genes for them are so rare that combinations will be nearly nonexistent.

Soon after selection begins, however, most of the surviving flies will have one of the characteristics that causes resistance. These characteristics are additive—that is, a fly with two of them will be considerably

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[2]Resistance is not known to have developed in insects feeding on rapidly growing herbaceous crops which soon die or are plowed under. No permanent surfaces for DDT deposits are provided by such plants, and DDT remains highly effective against many agricultural pests.

[3]A recessive characteristic is one which is undeveloped.

[4]A mutation is a sudden variation; the offspring differ markedly from their parents in some definite characteristic. This is unlike the situation where a change becomes well defined only in the course of many generations.

more resistant than a fly with only one. As a result of mating of parents which are slightly resistant for different reasons, some more resistant progeny will be produced; selection will eliminate the less resistant. As these processes continue through generations with continued selection, associations of resistant characteristics develop and resistance thus is due to numerous genes; it is said to be a multifactorially controlled. The flies will be far more resistant than any fly in the original population.

We hope that our studies, w' .n completed, will shed light on the validity of our assumptions. The practical problem remains, however—what do we do to control insects which have become resistant to all suitable insecticides and which do not lose resistance rapidly enough when selection is relaxed to make alternation of insecticides in different years effective? Of course one alternative is to go back to the control measures used before DDT was introduced—for example sanitation for houseflies. Undoubtedly this will be done more and more. Another idea is that insecticides should be used only where most needed, so that the resistance which does develop will be swamped in large populations of non-resistant flies.

Thomas A. Edison and Naval Research

On December 3, the Naval Research Laboratory unveiled a large bronze bust of Thomas A. Edison. The statue, which was cast several years ago by the noted American sculptress Evelyn B. Longman, was presented to the Laboratory by the Thomas Alva Edison Foundation. Supported by a cast-stone pedestal, it stands on the central mall, just inside the main gate.

In 1915, Mr. Edison was asked by Navy Secretary Daniels to organize and head the Naval Consulting Board of the United States. One of the first acts of that panel of eminent scientists was to recommend the construction of a naval laboratory. Edison wrote the specifications himself, outlining a research institution that would be commanded by a naval officer but staffed predominantly by civilians. Although funds for the laboratory were appropriated in 1916, it wasn't completed until 1923 and Mr. Edison never actually saw it. But the laboratory of today, in spite of its vastly increased size and scope, is in its organization, facilities for research, method of operation, and civilian character the embodiment of Edison's dream.

On The Naval Research Reserve

CDR Edmondson Makes Western Trip

RADM McManes

When the new Assistant Chief of Naval Operations for Naval Reserve, RADM Kenmore M. McManes, made his first inspection trip last month, CDR F. L. Edmondson, Chief of the Naval Research Reserve was invited to accompany him. RADM McManes was on his way to Cheyenne, Wyo. to accept a mural painted by the Cheyenne Artists' Guild for use at the U. S. Naval Training Center in that city. CAPT. T. Burrowes, Assistant Chief for Naval Reserve, BuPers, was also along on the trip.

CDR Edmondson reported fine results from his Western jaunt. He was able to attend a dinner meeting of VNRRU in Fort Collins, Wyo. and to visit units in the cities of Des Moines, Iowa, Albuquerque, N. M. and Los Alamos, N. M.

LCDR Churchill New Training Officer

LCDR Churchill

LCDR Elbert S. Churchill, formerly Chicago Program Officer, recently came to Washington to replace CDR George Z. Dimitroff, retiring Washington Training Officer. LCDR Churchill has just about divided his time evenly between his civilian scientific career and Navy duty. He had completed his work for his master's degree in bacteriology at Michigan State College and was a graduate assistant there when the war interrupted his academic pursuits. Service in the Navy during the Aleutians campaign and then in the Phillipines followed. After the war LCDR Churchill returned to Michigan State College on the faculty of the Department of Bacteriology, where he remained until February 1951. He then took the position of Program Officer in Chicago, where he remained until assigned to Washington.

University of Nebraska Honors Dr. Lugn


Dr. Lugn

Dr. Alvin L. Lugn, Professor of Geology and charter member of VNRRU 9-22, was recently honored by a certificate of appreciation from the University of Nebraska, where he has been teaching for some twenty-five years. The citation reads as follows:

The University of Nebraska deeply appreciates the services and loyalty of Alvin L. Lugn, member of its staff since 1927.

Professor of Geology since 1938, Dr. Lugn has been an effective teacher not only of his students but of the citizens of this state. His research work includes many significant contributions in the fields of sub-surface geology, deep well correlation, hydrology, water supply and sedimentation. These investigations have been of great value to Nebraska people in developing, utilizing and wisely husbanding the natural resources of their state.

The University of Nebraska takes great pleasure in presenting Alvin L. Lugn the Certificate of Appreciation which symbolizes this University's pride in his twenty-five years of loyal service and scholarship in the cause of higher learning.

/S/ R.G. Gustavson
Chancellor

VNRRU 1-5 Holds Third Anniversary Meeting

Volunteer Naval Research Reserve Unit 1-5, Worcester, Massachusetts, recently held its third anniversary dinner meeting at the Sheraton Hotel, Worcester, Massachusetts.

Commander Emerson A. Wiggin, USNR, Commanding Officer of the Unit was the Master of Ceremonies and introduced the guests of the evening: CAPT F. B. Eggers, USN, Director, ONR, Boston; Dr. Carl F. Muckenhoupt, Chief Scientist, ONR, Boston; and CDR H. Wray Rohrman, USNR, Reserve Program Officer, ONR, Boston; Dr. Muckenhoupt, guest speaker of the evening, presented a very fine picture of some of the unclassified projects in this area. Dr. Muckenhoupt, however, was in competition with the Republican presidential candidate who was speaking just outside of the hotel at the same time, but both seemed to hold their audiences without a numerical loss to either group.

VNRRU 3-5 Visits New London Submarine Base

In the group above are officers of VNRRU 3-5 who recently visited the Submarine Base at New London, Connecticut. A highly successful trip was reported, with special interest shown in the Medical Research Laboratory and the Diving Tower. The officers are, left to right: LTJG S. I. Brownell, LTJG J. A. Wheeler, CDR R. E. Mathes, LTJG P. J. Thomas, CDR K. I. Boone, LT W. K. Murray, LCDR B. Meulendyke, LTJG L. E. Robb, CDR J. H. Goldman, LT R. C. Maconi, CDR D. S. Rowell, LTJG H. N. Bowes, LTJG C. G. Fleisher, and LT C. E. Huntington. LT Maconi and LTJG Robb are not members of VNRRU 3-5, but are members of the volunteer composite unit in New Haven.

Promotion Zones to Captain and Commander Announced

CORPS	1 April 1951 Naval Reserve Register Number of Junior Officer in Zone	Convening Date
(a) To the grade of Captain:		
LINE	871	24 Nov 1952
CEC	028	2 Dec 1952
DC	048	2 Dec 1952
MC	267	2 Dec 1952
(b) To the grade of Commander		
LINE	20161	24 Nov 1952
MC	02138	2 Dec 1952
SC	01450	2 Dec 1952
CHC	00401	2 Dec 1952
CEC	01202	2 Dec 1952
DC	01378	2 Dec 1952
MSC	00071	2 Dec 1952

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Minimizing Electronics Maintenance, by W. McGuigan, August

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*Articles are arranged chronologically under the ONR Division and Branch which have cognizance of the research described.

+Written by the editorial staff of Research Reviews.

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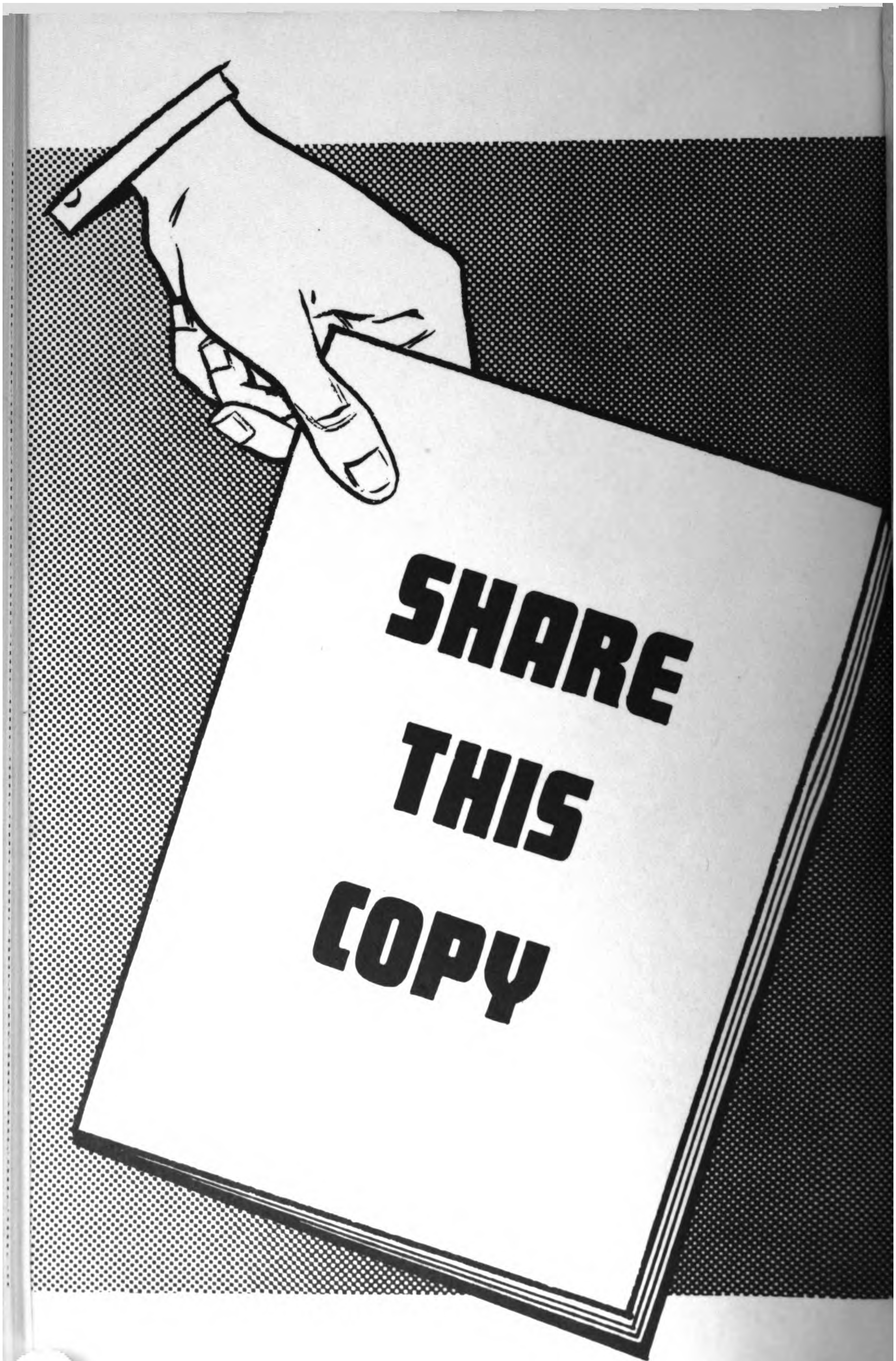
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